



**AFRL-SA-WP-SR-2017-0023**

# **Bioenvironmental Engineering Guide to Beryllium**



**Jon E. Black, Maj, USAF, BSC**



**July 2017**

**DISTRIBUTION STATEMENT A. Approved  
for public release. Distribution is unlimited.**

**STINFO COPY**

**Air Force Research Laboratory  
711<sup>th</sup> Human Performance Wing  
U.S. Air Force School of Aerospace Medicine  
Occupational & Environmental Health Dept  
Consultative Services Division  
2510 Fifth St., Bldg. 840  
Wright-Patterson AFB, OH 45433-7913**

# NOTICE AND SIGNATURE PAGE

Using Government drawings, specifications, or other data included in this document for any purpose other than Government procurement does not in any way obligate the U.S. Government. The fact that the Government formulated or supplied the drawings, specifications, or other data does not license the holder or any other person or corporation or convey any rights or permission to manufacture, use, or sell any patented invention that may relate to them.

Qualified requestors may obtain copies of this report from the Defense Technical Information Center (DTIC) (<http://www.dtic.mil>).

AFRL-SA-WP-SR-2017-0023 HAS BEEN REVIEWED AND IS APPROVED FOR PUBLICATION IN ACCORDANCE WITH ASSIGNED DISTRIBUTION STATEMENT.

//SIGNATURE//

---

DAVID R. CARPENTER, PhD, CIH, CSP  
Deputy, Occup & Environ Health Dept

//SIGNATURE//

---

WENDY E. ODDEN, Col, USAF, BSC, CIH  
Chair, Occup & Environ Health Dept

This report is published in the interest of scientific and technical information exchange, and its publication does not constitute the Government's approval or disapproval of its ideas or findings.

<b>REPORT DOCUMENTATION PAGE</b>				<i>Form Approved</i> <i>OMB No. 0704-0188</i>	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. <b>PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.</b>					
<b>1. REPORT DATE (DD-MM-YYYY)</b> 26 Jul 2017		<b>2. REPORT TYPE</b> Special Report		<b>3. DATES COVERED (From – To)</b> January 2017 – July 2017	
<b>4. TITLE AND SUBTITLE</b>  Bioenvironmental Engineering Guide to Beryllium				<b>5a. CONTRACT NUMBER</b>	
				<b>5b. GRANT NUMBER</b>	
				<b>5c. PROGRAM ELEMENT NUMBER</b>	
<b>6. AUTHOR(S)</b>  Jon E. Black, Maj, USAF, BSC				<b>5d. PROJECT NUMBER</b>	
				<b>5e. TASK NUMBER</b>	
				<b>5f. WORK UNIT NUMBER</b>	
<b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b> USAF School of Aerospace Medicine Occupational & Environmental Health Dept Consultative Services Division (USAFSAM/OEC) 2510 Fifth St., Bldg. 840 Wright-Patterson AFB, OH 45433-7913				<b>8. PERFORMING ORGANIZATION REPORT NUMBER</b>  AFRL-SA-WP-SR-2017-0023	
<b>9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b>				<b>10. SPONSORING/MONITOR'S ACRONYM(S)</b>	
				<b>11. SPONSOR/MONITOR'S REPORT NUMBER(S)</b>	
<b>12. DISTRIBUTION / AVAILABILITY STATEMENT</b>  DISTRIBUTION STATEMENT A. Approved for public release. Distribution is unlimited.					
<b>13. SUPPLEMENTARY NOTES</b> Cleared, 88PA, Case # 2017-3799, 3 Aug 2017.					
<b>14. ABSTRACT</b> This document provides guidance to Bioenvironmental Engineering personnel at base level on how to comply with the Occupational Safety and Health Administration's (OSHA) beryllium standard as promulgated in Code of Federal Regulations Title 29 Parts 1910.1024 and 1926.1124. This guide will help Bioenvironmental Engineering personnel provide supervisors and commanders the information and recommendations for documenting OSHA compliance and helping limit exposures to beryllium to below the action level and permissible exposure limit. This document supersedes previous documentation that does not incorporate the recent OSHA update to the beryllium final rule, 20 May 2017.					
<b>15. SUBJECT TERMS</b> Beryllium, expanded standard, OSHA, compliance, bioenvironmental engineering, exposure, risk assessment, CFR, measurement, safety					
<b>16. SECURITY CLASSIFICATION OF:</b>			<b>17. LIMITATION OF ABSTRACT</b>  SAR	<b>18. NUMBER OF PAGES</b>  22	<b>19a. NAME OF RESPONSIBLE PERSON</b> Col Wendy E. Odden
<b>a. REPORT</b> U	<b>b. ABSTRACT</b> U	<b>c. THIS PAGE</b> U			<b>19b. TELEPHONE NUMBER (include area code)</b>

*This page intentionally left blank.*

# TABLE OF CONTENTS

Section	Page
LIST OF FIGURES .....	ii
LIST OF TABLES .....	ii
1.0 SUMMARY .....	1
2.0 INTRODUCTION .....	1
2.1 Purpose .....	2
2.2 Beryllium Health Effects.....	2
2.3 Exposure Standards .....	3
3.0 BERYLLIUM REGULATION REQUIREMENTS.....	4
3.1 Overview .....	4
3.2 Written Exposure Control Plan .....	4
3.3 Regulated Areas .....	5
3.4 Medical Surveillance.....	5
3.5 Recordkeeping and Retention .....	6
3.6 Employee Notification .....	6
3.7 Demarcation of Regulated Areas .....	6
4.0 BERYLLIUM COMPLIANCE AND CONTROL.....	8
4.1 Baseline and Routine Workplace Assessment .....	8
4.2 Air Sampling .....	8
4.3 Engineering Controls.....	9
4.4 Administrative Controls .....	10
4.5 Personal Protective Clothing or Equipment .....	10
5.0 CONCLUSION.....	12
6.0 REFERENCES .....	12
BIBLIOGRAPHY .....	14
LIST OF ABBREVIATIONS AND ACRONYMS .....	15
GLOSSARY .....	16

## LIST OF FIGURES

	Page
Figure 1. Example of a beryllium regulated area sign .....	7
Figure 2. Example of a beryllium warning label .....	7

## LIST OF TABLES

	Page
Table 1. Exposure Limits for Airborne Beryllium Inhalation Hazards .....	4

## 1.0 SUMMARY

This document provides guidance to Bioenvironmental Engineering personnel at base level on how to comply with the Occupational Safety and Health Administration's (OSHA) beryllium standard as promulgated in Code of Federal Regulations Title 29 Parts 1910.1024 and 1926.1124. This guide will help Bioenvironmental Engineering personnel provide supervisors and commanders the information and recommendations for documenting OSHA compliance and helping limit exposures to beryllium to below the action level and permissible exposure limit. This document supersedes previous documentation that does not incorporate the recent OSHA update to the beryllium final rule, 20 May 2017.

## 2.0 INTRODUCTION

The Occupational Safety and Health Administration (OSHA) released updated beryllium standards for general industry, shipyard, and construction. This guide, intended for base-level occupational health program implementation, provides information on the Code of Federal Regulations (CFR) Title 29 Part 1910.1024 [1] for general industry and Part 1926.1124 [2] for construction and impact on Air Force (AF) operations. Any apparent conflicts between this document and others shall be resolved by defaulting to the CFR. All references in this document to beryllium standards apply to both OSHA general industry and construction regulations, and any differences between the two regulations are explicitly noted.

Beryllium is a hard, grayish metal naturally found in mineral rocks, coal, soil, and volcanic ash and resulting dust. Beryllium compounds are commercially mined and purified for use in a number of industrial applications. Generic industrial applications involving beryllium include nuclear weapons, aircraft and space vehicle structures, instruments, x-ray machines, and mirrors. Some specific AF applications involving beryllium include aircraft weapon systems, copper-beryllium alloy bushings and bearings, aluminum-beryllium alloys in forward-looking infrared thermal sensing/targeting systems, non-sparking tools, dental alloys, bead blasting, ammunition, and a contaminant in aluminum smelting and metal recycling. Beryllium alloys are used in commercial products as well. The beryllium standard applies to occupational exposure to beryllium in all forms, compounds, and mixtures in general industry; however, it does not apply to articles, as defined in the hazard communication standard [§1910.1200(c)] [3], that contain beryllium that the employer does not process [§1910.1024(a)(2) & §1926.1124(a)(2)]. It also does not apply to materials containing less than 0.1% beryllium by weight where the employer has objective data demonstrating that employee exposure to beryllium will remain below the action level (AL) as an 8-hour time-weighted average (TWA) under any foreseeable conditions [§1910.1024(a)(3) & §1926.1124(a)(3)].

This guide will assist with OSHA compliance, program implementation, and exposure control. The beryllium standard is more than just a revised permissible exposure limit (PEL); it is an entire compliance standard for general industry, shipyard, and construction. The most notable changes are that OSHA reduced the 8-hour TWA PEL by a factor of 10 from 2.0  $\mu\text{g}/\text{m}^3$  to 0.2  $\mu\text{g}/\text{m}^3$  [§1910.1024(c)(1) & §1926.1124(c)(1)]. OSHA also eliminated the 5.0- $\mu\text{g}/\text{m}^3$  ceiling limit, introduced a 15-minute short-term exposure limit (STEL) of 2.0  $\mu\text{g}/\text{m}^3$  [§1910.1024(c)(2) & §1926.1124(c)(2)], and added provisions to prevent skin contact [§1910.1024(b) & §1926.1124(f)(1)(i)(A)]. This guide will assist with base-level occupational health risk management decisions and OSHA compliance.

If after reading this document you want more information, contact the Environmental, Safety, and Occupational Health (ESOH) Service Center at DSN 798-3764, 1-888-232-ESOH (3764), or [esoh.service.center@us.af.mil](mailto:esoh.service.center@us.af.mil).

## **2.1 Purpose**

The purpose of this guide is to assist with base-level occupational health risk management decisions and OSHA compliance regarding beryllium exposures. Although beryllium does not receive the media attention that other metals such as lead or mercury receive, it can lead to significant negative health effects, particularly preventable lung diseases, and accounts for an estimated 96 deaths per year. In general, the AF must assess the airborne exposure of each employee who is, or may reasonably be expected to be, exposed to airborne beryllium in accordance with either the performance option or a scheduled monitoring option as specified in the standard [§1910.1024(d) & §1926.1124(d)]. An analysis of data in the Defense Occupational and Environmental Health Readiness System (DOEHRS) conducted in February 2017 identified 1,124 personnel exposed to beryllium due to 51 processes performed in 42 industrial shops at 26 bases. This analysis found 94 air sampling events for the 578 beryllium workplace hazards entered in DOEHRS. Taking into consideration the number of processes and workplace hazards involving beryllium, there appears to be a significant deficiency in beryllium air sampling exposure assessments across the AF. Additionally, the AF must reassess airborne exposure whenever a change in the production, process, control equipment, personnel, or work practices may reasonably be expected to result in new or additional airborne exposure at or above the AL or STEL, or when there is any reason to believe that new or additional airborne exposure at or above the AL or STEL has occurred. The sampling and analytical challenges associated with measuring beryllium are greater than most other metals due to the new final rule. Bioenvironmental Engineering (BE) personnel should be able to identify potential inhalation and dermal hazards; recommend personal protective equipment (PPE) or clothing, decontamination procedures, and engineering controls; and select the most suitable sampling strategy and method for a given scenario.

## **2.2 Beryllium Health Effects**

Exposure to beryllium in the form of beryllium-containing dust, fume, mist, or solutions typically occurs via inhalation or skin contact. Systemic health effects from exposure to beryllium by ingestion are less concerning since beryllium is not well absorbed through the gastrointestinal tract. Health effects associated with overexposure to beryllium in the workplace may include acute chemical pneumonitis, beryllium sensitization, dermatitis, chronic beryllium disease (CBD), and lung cancer as explained in the following.

Acute chemical pneumonitis occurs when a high concentration ( $>100 \mu\text{g}/\text{m}^3$ ) of beryllium is inhaled for a short period (15 minutes or less), and after a few hours of latency may be presented as labored breathing, chest pain, bronchial spasm, fever, cough, blood-tinged sputum, and nasal discharge [4]. Acute chemical pneumonitis is not common and would most likely be related to cases involving an isolated industrial accident. Recovery from acute chemical pneumonitis may take 1 to 12 weeks [5].



Beryllium sensitization is the activation of the body's immune response to beryllium. OSHA estimates that between 1% and 15% of the population is potentially vulnerable and carries the potential to be sensitive to beryllium [6]. Beryllium sensitization can result from inhalation or skin exposure to beryllium dust, fume (such as welding smoke), mist, or solutions. While no clinical symptoms are associated with the process of sensitization, once sensitized, a worker is at higher risk of developing CBD with repeated episodes of inhalation exposure to beryllium.

Dermal contact with beryllium can result in dermatitis resembling first- or second-degree burns and skin granulomas [7]. Beryllium dust, fume, mist, and solutions also may be irritating to the eyes, leading to bloodshot conjunctiva, persistent burning sensation, and sensitivity to light [8].

CBD, sometimes called berylliosis, is an immunological lung disease caused by long-term exposure to low levels of beryllium. Chronic berylliosis is a pulmonary and systemic granulomatous disease caused by inhalation of dust or fumes contaminated with beryllium; either large amounts over a short time or small amounts over a long time can lead to this ailment. Symptoms of the disease can take up to 5 years to develop; about a third of patients with it die and the survivors are left disabled [9]. It is characterized by anorexia, weight loss, lassitude (weakness, exhaustion), chest pain, cough, clubbing of fingers, cyanosis, pulmonary insufficiency (shortness of breath), irritation of eyes, and dermatitis. CBD can progress to a serious and life-threatening disease if left undiagnosed and beryllium exposure continues. After initial exposure to beryllium, some workers may quickly develop signs and severe symptoms of CBD. Personnel may not experience signs and symptoms until months or years after initial exposure. Symptoms can sometimes worsen even after the worker has been removed from exposure. CBD can progress to a chronic obstructive lung disorder, resulting in loss of quality of life and the potential for decreased life expectancy.

The International Agency for Research on Cancer classifies beryllium as a Group 1 carcinogen (carcinogenic to humans), and the National Toxicology Program lists beryllium as a known human carcinogen. Airborne beryllium dust is a confirmed lung carcinogen; consequently, the AF **must** assess the airborne exposure of each employee who is or may reasonably be expected to be exposed to airborne beryllium in accordance with either the performance option or a scheduled monitoring option as specified in the standard.

## 2.3 Exposure Standards

Table 1 provides a summary of the exposure limit changes due to the beryllium standard update. In addition to the TWA PEL and AL, OSHA added a 15-minute STEL. Whenever an exposure assessment indicates that airborne exposure is above the TWA PEL or STEL, the employer must describe in the written notification to employees the corrective action(s) being taken to reduce airborne exposure to or below the exposure limit(s) exceeded [§1910.1024(d)(6)(ii) & §1926.1124(d)(6)(ii)].

**Table 1. Exposure Limits for Airborne Beryllium Inhalation Hazards**

<b>Exposure Limit Type</b>	<b>Previous OSHA Standard (<math>\mu\text{g}/\text{m}^3</math>)</b>	<b>New OSHA Standard (<math>\mu\text{g}/\text{m}^3</math>)</b>
8-h TWA PEL	2.0	0.2
Short-duration PEL	25.0 <sup>a</sup>	2.0 <sup>b</sup>
AL	1.0	0.1

Note: §1910.1024(b), §1910.1024(c), §1926.1124(b), & §1926.1124(c).

<sup>a</sup>30-min peak TWA.

<sup>b</sup>15-min STEL.

## **3.0 BERYLLIUM REGULATION REQUIREMENTS**

### **3.1 Overview**

Demonstrating compliance with the OSHA beryllium standard starts with administrative management and controls practices. Accurate and up-to-date policy, records, training, and protection of worker methods are the foundation of an effective beryllium worker protection program.

The new beryllium standard became effective on May 20, 2017. Most provisions of the new beryllium standard take effect on March 12, 2018. The requirement to provide showers (for general industry) and change rooms (for all industries) takes effect on March 11, 2019, and the engineering controls requirement takes effect on March 10, 2020 [§1910.1024(o)(2) & §1926.1124(o)(2)].

### **3.2 Written Exposure Control Plan**

OSHA requires a written exposure control plan [§1910.1024(f)(1) & §1926.1124(f)(1)], a written housekeeping plan [§1910.1024(j) & §1926.1124(j)], and established beryllium work area and regulated area controls [§1910.1024(e) & §1926.1124(f)(1)(i)(I)], all of which are largely unchanged from the previous beryllium standard, except that it now also requires the above-mentioned items for areas where potential dermal contact with beryllium exists.

If areas exist in a facility with the potential for airborne exposure or skin contact with beryllium, then operations and job titles for employees working in these areas must be identified in a written exposure control plan [§1910.1024(f)(1)(i)(A) & §1926.1124(f)(1)(i)(A)]. This plan must delineate areas in the facility where there is any potential for exposure, exposures above the AL, and exposures above the PEL. The plan must identify other requirements in the different exposure areas (housekeeping, respiratory protection, PPE, etc.) [§1910.1024(f)(1)(i) & §1926.1124(f)(1)(i)]. These plans must be reviewed annually [§1910.1024(f)(1)(ii) & §1926.1124(f)(1)(ii)]. A written exposure control plan template is available on the ESOH Service Center website (<https://hpws.afrl.af.mil/dhp/OE/ESOHSC/index.cfm>) and can be accessed by clicking the “Occupational Health” and then “Beryllium” links.

### 3.3 Regulated Areas

The term “regulated area” means an area, including temporary work areas where maintenance or non-routine tasks are performed, where an employee’s airborne exposure exceeds, or can reasonably be expected to exceed, either the 8-hour TWA PEL or 15-minute STEL [§1910.1024(b)]. The employer must provide and display warning signs at each approach to a regulated area so that each employee is able to read and understand the signs and take necessary protective steps before entering the area [§1910.1024(e)(2)].

Beryllium work areas are defined as any work area where employees are, or can reasonably be expected to be, exposed to airborne beryllium, regardless of the level of exposure, or where the potential for skin contact exists [§1910.1024(b)]. Beryllium work areas must be designated by signs or other means [§1910.1024(e)(2) & §1926.1124(f)(1)(i)(I)]. Examples of work processes and operations exhibiting a potential for dermal contact with beryllium are maintenance, metals technology, welding, abrasive blasting, and pneumatic sanding operations. OSHA also requires that procedures for minimizing cross-contamination or the migration of beryllium from work areas to other locations are in place [§1910.1024(f)(1)(i)(D) & §1926.1124(f)(1)(i)(D)] and that high-efficiency particulate air (HEPA) filter vacuuming or wet cleaning methods are used for cleaning beryllium work areas [§1910.1024(j)(2) & §1926.1124(j)(2)].

### 3.4 Medical Surveillance

The beryllium standard requires criteria-based medical surveillance. Under the beryllium standard [1,2], OSHA requires medical surveillance for workers who meet worker-specified criteria: 1) are reasonably expected to be exposed above the AL of 0.1  $\mu\text{g}/\text{m}^3$  for 30 or more days in a year, 2) show signs or symptoms of CBD, 3) were exposed to beryllium during an emergency, or 4) have received a recommendation for continued medical surveillance from a physician or other licensed healthcare professional (PLHCP) from the most recent exam [§1910.1024(k)(1)(i) & §1926.1124(k)(1)(i)]. Civilian employees may opt out of the medical surveillance program if they so choose [§1910.1024(k)(3)(i) & §1926.1124(k)(3)(i)]. Employers must offer beryllium-related medical surveillance to a worker within 30 days of meeting the criteria and continue at least every 2 years thereafter for those who continue to meet the criteria [§1910.1024(k)(2) & §1926.1124(k)(2)].

The medical examination must include the following: 1) medical and work history with emphasis on past and present airborne exposure to or dermal contact with beryllium, smoking history, and any history of respiratory system dysfunction; 2) physical examination with emphasis on the respiratory system and for skin rashes; 3) pulmonary function tests; 4) beryllium lymphocyte proliferation test (BeLPT), or other equivalent test; and 5) any other test deemed appropriate by the PLHCP (including low-dose computed tomography scan) [§1910.1024(k)(3)(ii) & §1926.1124(k)(3)(ii)]. OSHA requires new medical monitoring provisions, including referral to a CBD diagnostic center and follow-up BeLPTs. Continued periodic medical surveillance is recommended for employees who are confirmed positive for sensitization or diagnosed with CBD [§1910.1024(k)(5)(iii) & §1926.1124(k)(5)(iii)]. Medical monitoring for beryllium workers as outlined in the final rule at least every 2 years is achievable as long as personnel meeting the 30-day criteria are properly identified within the Aeromedical Services Information Management System.

### **3.5 Recordkeeping and Retention**

The employer must make and maintain records of the objective data relied upon for compliance with this standard. Reference the beryllium standard objective data recordkeeping requirements when using sampling to document an exposure assessment for compliance purposes [§1910.1024(n)(2) & §1926.1124(n)(2)]. The AF must ensure all air monitoring samples used to satisfy the monitoring requirements of the standard are evaluated by a laboratory that can measure beryllium to an accuracy of  $\pm 25\%$  within a statistical confidence level of 95% for airborne concentrations at or above the AL [§1910.1024(d)(5) & §1926.1124(d)(5)]. The AF must ensure all air monitoring samples used to satisfy the monitoring requirements of the standard are at least 420 minutes in length for TWA samples. Sampling for less than 420 minutes for a given work shift does not meet the OSHA requirement regardless of the length of time of the task.

Upon request, the employer must make all records maintained as a requirement of this standard available for examination and copying to the Assistant Secretary of Labor, the Director of the National Institute for Occupational Safety and Health (NIOSH), each employee, and each employee's designated representative as stipulated by OSHA's records access standard, 29 CFR 1910.1020 [10]. For the Department of Defense and the AF, the DOEHS industrial hygiene module is the required and only acceptable location to maintain all occupational and environmental health exposure records.

### **3.6 Employee Notification**

If employees have a potential for beryllium exposure, then the employees' 8-hour TWA and 15-minute exposures must be determined by personal monitoring or the use of air sampling data that reflect the employees' exposures [§1910.1024(d)(1) & §1926.1124(d)(1)]. If personal monitoring is used, then employees must be notified of personal monitoring results. Employee notification requirements have not changed with this standard. Employees must be notified within 15 working days after exposure results are received. The AF must notify each employee whose airborne exposure is represented by the assessment of results in writing or by posting the results in an appropriate location that is accessible to each of these employees [§1910.1024(d)(6) & §1926.1124(d)(6)].

### **3.7 Demarcation of Regulated Areas**

The employer must provide and display warning signs at each approach to a regulated area so that each employee is able to read and understand the signs and take necessary protective steps before entering the area [§1910.1024(e)(2)]. These warning requirements are meant to reduce confusion and ambiguity regarding critical hazard information communicated in the workplace by requiring that this information be presented in a clear and uniform manner. Warning sign specifications as well as labeling requirements are outlined in the standard and should be incorporated into the written exposure control plan [§1910.1024(m)(2), §1910.1024(m)(3), & §1926.1124(m)(2)]. Examples of a beryllium regulated area sign and warning label are shown in Figures 1 and 2, respectively.



Figure 1. Example of a beryllium regulated area sign.



Figure 2. Example of a beryllium warning label.

## **4.0 BERYLLIUM COMPLIANCE AND CONTROL**

### **4.1 Baseline and Routine Workplace Assessment**

All processes that involve beryllium require a baseline assessment to determine inhalational and dermal exposures, potential beryllium work area classification, and support determination of worker occupational medical exams [§1910.1024(d) & §1926.1124(d)]. BE should assess inhalational exposures by collecting at least six full shift samples for each potentially affected similar exposure group. Assessments should be made within 30 days of the initiation of a new process or notification of a change in an existing process [§1910.1024(d)(4) & §1926.1124(d)(4)]. BE should verify whether or not changes to existing processes have occurred as a part of the periodic assessments at industrial work centers at the prescribed frequencies for Category 1 or 2 shops.

### **4.2 Air Sampling**

The OSHA beryllium standard requires employers to assess the airborne exposure of each employee who is or may reasonably be expected to be exposed to airborne beryllium. OSHA has determined that the current sampling and analytical methods (NIOSH 7300 and OSHA 125G) available to employers are sufficient to measure beryllium as required in the final rule. The U.S. Air Force School of Aerospace Medicine (USAFSAM) Analytical Services Division industrial hygiene lab supports the NIOSH 7300 method. Where air sampling is required, the AF must perform initial monitoring, which should include at least six valid samples, to assess the short-term exposure from 15-minute personal breathing zone air samples measured in operations that are likely to produce airborne exposure above the STEL for each work shift, for each job classification, and in each beryllium work area. Where several employees perform the same tasks on the same shift and in the same beryllium work area, the employer may sample a representative fraction of these employees to meet the requirements [§1910.1024(d)(3)(iii) & §1926.1124(d)(3)(iii)]. In representative sampling the AF must sample the employee(s) expected to have the highest airborne exposure to beryllium. When six valid full shift samples have been analyzed and the statistical analysis of their results indicate with 95% confidence that airborne exposures are below the AL, as well as the same for 15-minute personal breathing zone air samples being at or below the STEL, the employer may discontinue monitoring for those employees whose airborne exposure is represented by such monitoring [§1910.1024(d)(3)(iv) & §1926.1124(d)(3)(iv)].

OSHA requires that air sampling must be repeated within 6 months where employee exposures are between the AL and the TWA PEL [§1910.1024(d)(3)(v) & §1926.1124(d)(3)(v)] and within 3 months where employee exposures are above the TWA PEL or STEL [§1910.1024(d)(3)(vi) & §1926.1124(d)(3)(vi)]. If exposure monitoring continues to indicate airborne exposure is at or above the AL and at or below the TWA PEL, the employer must repeat such monitoring within 6 months of the most recent monitoring. Where exposure monitoring indicates airborne exposure is above the TWA PEL, the employer must repeat such monitoring within 3 months of the most recent 8-hour TWA exposure monitoring. Where the most recent (non-initial) exposure monitoring indicates that airborne exposure is below the AL, the employer must repeat such monitoring within 6 months until two consecutive measurements, taken 7 or more days apart, are below the AL, at which time the employer may discontinue 8-hour TWA

exposure monitoring for those employees whose exposure is represented by such monitoring [§1910.1024(d)(3)(vii) & §1926.1124(d)(3)(vii)].

Based on the DOEHRs data analysis conducted in February 2017, if 6 air sampling events were conducted on the 578 workplace beryllium hazards, then there should be at least 3,468 air sampling events for beryllium in the DOEHRs. However, this analysis identified only 94 air sampling events for beryllium, which suggests that only 3% of the necessary air sampling events for initially characterizing beryllium exposures across the AF have been completed. For the 94 air sampling events for beryllium, 40 air samples were above the beryllium AL and 21 were above the beryllium PEL. These beryllium exposures above the AL and PEL require periodic monitoring requirements that will further increase the deficiency in beryllium air sampling across the AF if corrective actions are not implemented. Additionally, until all beryllium work areas and regulated areas have been fully identified and assessed, there will likely be a corresponding deficiency in medical surveillance for personnel exposed to beryllium.

If the beryllium exposure is above the OSHA PEL of  $0.2 \mu\text{g}/\text{m}^3$ , then the exposure profile is uncontrolled. In cases where the exposure profile is uncontrolled, additional control efforts must be instituted to meet OSHA compliance requirements. The implementation of additional control efforts should be considered by following the control hierarchy of engineering [§1910.1024(f)(2) & §1926.1124(f)(2)], substitution, administrative [§1910.1024(g) & §1926.1124(g)], and PPE [§1910.1024(h) & §1926.1124(h)].

#### **4.3 Engineering Controls**

For each operation in a beryllium work area that releases airborne beryllium, the employer must ensure that at least one of the following is in place to reduce airborne exposure: 1) material and/or process substitution; 2) isolation, such as ventilated partial or full enclosures; 3) local exhaust ventilation; or 4) process control, such as wet methods and automation. The employer may be exempt from using engineering controls only if very specific criteria outlined in the beryllium standard can be met and properly documented [§1910.1024(f)(2)(ii) & §1926.1124(f)(2)(ii)]. Recommend coordinating with USAFSAM Occupational and Environmental Health Department and your major command BE if this option is being considered.

For each employee working in a beryllium work area, the employer must 1) provide readily accessible washing facilities in accordance with the beryllium standard and the sanitation standard to remove beryllium from the hands, face, and neck and 2) ensure that employees who have dermal contact with beryllium wash any exposed skin at the end of the activity, process, or work shift and prior to eating, drinking, smoking, chewing tobacco or gum, applying cosmetics, or using the toilet. In addition, the employer must provide employees who work in a beryllium work area with a designated change room in accordance with the beryllium standard and the sanitation standard where employees are required to remove personal clothing. The employer must provide showers in accordance with the sanitation standard where 1) airborne exposure exceeds, or can reasonably be expected to exceed, the TWA PEL or STEL and 2) beryllium can reasonably be expected to contaminate employees' hair or body parts other than hands, face, and neck (§1910.1024(i), §1926.1124(i), & §1910.141).

#### 4.4 Administrative Controls

The employer must establish, implement, and maintain a written exposure control plan and comply with specified elements in the standard [§1910.1024(f)(1) & §1926.1124(f)(1)]. The employer must review and evaluate the effectiveness of each written exposure control plan at least annually and update it as necessary [§1910.1024(f)(1)(ii) & §1926.1124(f)(1)(ii)]. The employer must not rotate employees to different jobs to achieve compliance with the PELs [§1910.1024(f)(3) & §1926.1124(f)(3)]. The employer must also establish and maintain a regulated area wherever employees are, or can reasonably be expected to be, exposed to airborne beryllium at levels above the TWA PEL or STEL [§1910.1024(e)(1)(ii)]. The boundaries of regulated areas would typically be the walls of the room or building where a process is performed. However, if air sampling results for personnel indicate that airborne beryllium exposures for other areas in a room or building where a process is performed are below the TWA PEL and STEL, then those areas could be identified as non-regulated areas and regulated area boundaries appropriately delineated and marked. The employer must identify each beryllium work area through signs or any other methods that adequately establish and inform each employee of the boundaries of each beryllium work area [§1910.1024(e)(1)(i)]. The employer must ensure that surfaces in beryllium work areas are cleaned by HEPA-filtered vacuuming or other methods that minimize the likelihood and level of airborne exposure [§1910.1024(j)(2) & §1926.1124(j)(2)].

Employees who have the potential for any beryllium exposure must be trained initially and annually on the health hazards of beryllium, processes where beryllium is being used, methods of protection, beryllium work areas, beryllium regulated areas (if any), and all other required program elements [§1910.1024(m)(4)(i) & §1926.1124(m)(3)(i)]. As a result of training, employees must be able to demonstrate knowledge of the training. Hazard communication standard training must include, among other things, the following:

1) information on the health hazards associated with airborne exposure to and dermal contact with beryllium; 2) the signs and symptoms of CBD; 3) information on the purpose, proper selection, fitting, proper use, and limitations of PPE; 4) any protective measures workers can take to protect themselves from airborne or skin exposure to beryllium (including personal hygiene practices); and 5) the purpose and description of the medical surveillance program and medical removal protection [§1910.1024(m)(4)(ii) & §1926.1124(m)(3)(ii)]. Training presentations have been updated with the new requirements and are available on the ESOH Service Center website (<https://hpws.afrl.af.mil/dhp/OE/ESOHSC/index.cfm>) and can be accessed by clicking the “Occupational Health” and then “Beryllium” links.

#### 4.5 Personal Protective Clothing or Equipment

PPE is required when airborne exposures can exceed the PEL or STEL, or the potential for skin exposure exists [§1910.1024(h)(1) & §1926.1124(h)(1)]. The employer must ensure that each employee removes all beryllium-contaminated PPE at the end of the work shift, at the completion of tasks involving beryllium, or when PPE becomes visibly contaminated with beryllium, whichever comes first [§1910.1024(h)(2)(i) & §1926.1124(h)(2)(i)]. The employer must ensure that all reusable PPE required by the standard is cleaned, laundered, repaired, and replaced as needed to maintain its effectiveness [§1910.1024(h)(3)(iii) & §1926.1124(h)(3)(iii)]. The employer must ensure that beryllium is not removed from PPE by blowing, shaking, or any



other means or dry methods that disperse beryllium into the air [§1910.1024(h)(3)(ii) & §1926.1124(h)(3)(ii)].

Under the beryllium standard, although some PPE may be worn over street clothing, it is not appropriate for workers to wear PPE over street clothing if doing so could reasonably result in contamination of the workers' street clothes. In situations in which it is not appropriate for workers to wear PPE over street clothes, employers must select and ensure the use of PPE that is worn in lieu of (rather than over) street clothing [§1910.1024(h)(1) & §1926.1124(h)(1)]. Additionally, employers must provide change rooms for employees where PPE must be used [§1910.1024(i)(2) & §1926.1124(i)(2)]. The employer must also provide washing facilities for clothes [§1910.1024(h)(2) & §1926.1124(h)(2)]. OSHA requires that procedures for minimizing cross-contamination or the migration of beryllium from work areas to other locations are in place and that wet cleaning methods are used for cleaning beryllium work areas [§1910.1024(j)(2) & §1926.1124(j)(2)]. These requirements are consistent with other 29 CFR 1910 expanded standards.

Personnel who abrade material containing beryllium that leads to the potential release of particulates may wear a NIOSH-approved N95 filtering facepiece device so long as the exposure has been shown to be below the TWA PEL and STEL (§1910.134) [11]. The AF must provide respiratory protection at no cost to the employee and ensure that each employee uses respiratory protection when required [§1910.1024(g)(1) & §1926.1124(g)(1)]. Personnel wearing any respirator must meet all the respiratory protection program requirements. Enrollment in the respiratory protection program is governed by Air Force Instruction 48-137, *Respiratory Protection Program* [12]; consult this document for additional guidance and requirements. OSHA has added a provision concerning employee respirator preference. The employer must provide at no cost to the employee a powered air-purifying respirator (PAPR) instead of a negative pressure respirator when 1) respiratory protection is required by this standard, 2) an employee entitled to such respiratory protection requests a PAPR, and 3) the PAPR provides adequate protection to the employee in accordance with the standard [§1910.1024(g)(3) & §1926.1124(g)(3)]. Disposable Tyvek® coveralls should be worn where the potential exists for airborne beryllium dust to be deposited on clothing [§1910.1024(h)(1) & §1926.1124(h)(1)]. For example, coveralls should be worn when materials are abraded either by sanding, blasting, or environmental conditions (i.e., high winds). The employer must ensure that each employee stores and keeps beryllium-contaminated PPE separate from street clothing and that storage facilities prevent cross-contamination [§1910.1024(h)(2)(iii) & §1926.1124(h)(2)(iii)]. The employer must ensure that no employee removes beryllium-contaminated PPE from the workplace, except for employees authorized to do so for the purposes of laundering, cleaning, maintaining, or disposing of beryllium-contaminated PPE at an appropriate location or facility away from the workplace [§1910.1024(h)(2)(iv) & §1926.1124(h)(2)(iv)]. When PPE required by this standard is removed from the workplace for laundering, cleaning, maintenance, or disposal, the employer must ensure that PPE is stored and transported in sealed bags or other closed containers that are impermeable and are appropriately labeled [§1910.1024(h)(2)(v) & §1926.1124(h)(2)(v)].

Gloves should be worn when handling beryllium dust-coated material to reduce the physical contact-sensitization hazard [§1910.1024(h)(1)(ii) & §1926.1124(h)(1)(ii)]. Gloves should be disposed with or in like manner to disposable Tyvek® coveralls as noted above [§1910.1024(h)(2)(iii) & §1926.1124(h)(2)(iii)].

Full-face respiratory protection or goggles are recommended whenever material is disturbed such that the material can potentially become airborne [§1910.1024(h)(1)(ii) & §1926.1124(h)(1)(ii)].

## 5.0 CONCLUSION

This guide focused on the OSHA beryllium standard and the requirements it imposes on the AF due to hazards encountered, controls required to mitigate the health risk, and documentation required to attain compliance. Activities of concern include, but are not limited to, welding, sanding, corrosion control blasting, metal fabrication, mechanical depainting and desealing, weapons firing, and tool etching processes with materials containing beryllium. During day-to-day operations, the AF community needs to undertake a dedicated effort to characterize beryllium hazards, mitigate the health risk, and conduct the requisite number of sampling events for the beryllium hazard to demonstrate OSHA compliance.

Updates to this document as well as additional documentation on beryllium can be found on the ESOH Service Center website (<https://hpws.afrl.af.mil/dhp/OE/ESOHSC/index.cfm>) and can be accessed by clicking the “Occupational Health” and then “Beryllium” links.

## 6.0 REFERENCES

1. Chang, LW, editor. Toxicology of metals. Boca Raton (FL): Lewis Publishers; 1996:929-930.
2. Clayton GD, Clayton FE, editors. Patty’s industrial hygiene and toxicology, 3<sup>rd</sup> ed. Volumes 2A, 2B, 2C. New York (NY): John Wiley & Sons; 1982:1551.
3. Berlin JM, Taylor JS, Sigel JE, Bergfeld WF, Dweik RA. Beryllium dermatitis. J Am Acad Dermatol. 2003; 49(5):939-941.
4. Grant WM. Toxicology of the eye: effects on the eyes and visual system from chemicals, drugs, metals and mineral, plants, toxins and venoms: also, systemic side effects from eye medications, 3<sup>rd</sup> ed. Springfield (IL): Charles C. Thomas Publisher; 1986:144.
5. Emsley J. Nature’s building blocks: an A-Z guide to the elements. Oxford (UK): Oxford University Press; 2001.
6. U.S. Air Force. Respiratory protection program. Washington (DC): Department of the Air Force; 2014. Air Force Instruction 48-137.
7. Occupational Safety and Health Administration. Beryllium. (n.d.). [Accessed 21 Apr 2017]. Available from <https://www.osha.gov/SLTC/beryllium/>.
8. National Archives and Records Administration. Toxic and hazardous substances. Beryllium. 29 CFR §1910.1024 (2017). [Accessed 21 Apr 2017]. Available from [https://www.ecfr.gov/cgi-bin/text-idx?SID=109a18424402ae8b2d6c1c2d65641c83&mc=true&node=se29.6.1910\\_11024&rgn=div8](https://www.ecfr.gov/cgi-bin/text-idx?SID=109a18424402ae8b2d6c1c2d65641c83&mc=true&node=se29.6.1910_11024&rgn=div8).
9. National Archives and Records Administration. Safety and health regulations for construction. Beryllium. 29 CFR §1926.1124 (2017). [Accessed 21 Apr 2017]. Available from [https://www.ecfr.gov/cgi-bin/text-idx?SID=109a18424402ae8b2d6c1c2d65641c83&mc=true&node=se29.8.1926\\_11124&rgn=div8](https://www.ecfr.gov/cgi-bin/text-idx?SID=109a18424402ae8b2d6c1c2d65641c83&mc=true&node=se29.8.1926_11124&rgn=div8).

10. National Archives and Records Administration. Toxic and hazardous substances. Hazard communication. 29 CFR §1910.1200 (2017). [Accessed 21 Apr 2017]. Available from [https://www.ecfr.gov/cgi-bin/text-idx?SID=109a18424402ae8b2d6c1c2d65641c83&mc=true&node=se29.6.1910\\_11200&rgn=div8](https://www.ecfr.gov/cgi-bin/text-idx?SID=109a18424402ae8b2d6c1c2d65641c83&mc=true&node=se29.6.1910_11200&rgn=div8).
11. National Archives and Records Administration. Toxic and hazardous substances. Access to employee exposure and medical records. 29 CFR §1910.1020 (2011). [Accessed 21 Apr 2017]. Available from [https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=109a18424402ae8b2d6c1c2d65641c83&mc=true&n=pt29.6.1910&r=PART&ty=HTML#se29.6.1910\\_11020](https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=109a18424402ae8b2d6c1c2d65641c83&mc=true&n=pt29.6.1910&r=PART&ty=HTML#se29.6.1910_11020).
12. National Archives and Records Administration. Personal protective equipment. Respiratory protection. 29 CFR §1910.134 (2011). [Accessed 21 Apr 2017]. Available from [https://www.ecfr.gov/cgi-bin/text-idx?SID=550313c68a3d914ef7d8aef22d8aa10f&mc=true&node=se29.5.1910\\_1134&rgn=div8](https://www.ecfr.gov/cgi-bin/text-idx?SID=550313c68a3d914ef7d8aef22d8aa10f&mc=true&node=se29.5.1910_1134&rgn=div8).

## BIBLIOGRAPHY

- Agency for Toxic Substances & Disease Registry. Beryllium toxicity cover page. 2011 May 23. [Accessed 7 Feb 2017]. Available from <http://www.atsdr.cdc.gov/csem/csem.asp?csem=5&po=0>.
- Aizenberg V, England E, Grinshpun S, Willeke K, Carlton G. Metal exposure among abrasive blasting workers at four U.S. Air Force facilities. *Appl Occup Environ Hyg*. 2000; 15(10):766-772.
- American Conference of Governmental Industrial Hygienists. Documentation of the threshold limit values and biological exposure indices, 7th ed. Cincinnati (OH): American Conference of Governmental Industrial Hygienists; 2015.
- Los Alamos National Laboratory. Los Alamos National Laboratory (LANL) responses to the Department of Energy request for information regarding possible new requirements in the beryllium rule (10 CFR 850). Los Alamos (NM): Los Alamos National Laboratory; 2011 Feb 22. Reference ESH&Q-11-010. [Accessed 21 Apr 2017]. Available from [https://energy.gov/sites/prod/files/2015/04/f21/22\\_J.Chris%20Cantwell\\_10%20CFR%20850%20Request%20for%20Information\\_Docket%20Number\\_HS\\_RM-10\\_CBDPP.pdf](https://energy.gov/sites/prod/files/2015/04/f21/22_J.Chris%20Cantwell_10%20CFR%20850%20Request%20for%20Information_Docket%20Number_HS_RM-10_CBDPP.pdf).
- National Institute for Occupational Safety and Health. Beryllium. 2017 Jan 13. [Accessed 21 Apr 2017]. Available from <http://www.cdc.gov/niosh/topics/beryllium/>.
- National Institute for Occupational Safety and Health. NIOSH pocket guide to chemical hazards. Cincinnati (OH): National Institute for Occupational Safety and Health; 2015.
- National Toxicity Program. Scientific review of beryllium and beryllium compounds. 2016 May 4. [Accessed 21 Apr 2017]. Available from <http://ntp.niehs.nih.gov/index.cfm?objectid=BD3E01E5-F1F6-975E-72262D55370B962D>.
- Occupational Safety and Health Administration. Final rule to protect workers from beryllium exposure. (n.d.). [Accessed 21 Apr 2017]. Available from <https://www.osha.gov/berylliumrule/index.html>.

## **LIST OF ABBREVIATIONS AND ACRONYMS**

<b>AF</b>	Air Force
<b>AL</b>	action level
<b>BE</b>	Bioenvironmental Engineering
<b>BeLPT</b>	beryllium lymphocyte proliferation test
<b>CBD</b>	chronic beryllium disease
<b>CFR</b>	Code of Federal Regulations
<b>DOEHRS</b>	Defense Occupational and Environmental Health Readiness System
<b>ESOH</b>	Environmental, Safety, and Occupational Health
<b>HEPA</b>	high-efficiency particulate air
<b>NIOSH</b>	National Institute for Occupational Safety and Health
<b>OSHA</b>	Occupational Safety and Health Administration
<b>PAPR</b>	powered air-purifying respirator
<b>PEL</b>	permissible exposure limit
<b>PLHCP</b>	physician or other licensed healthcare professional
<b>PPE</b>	personal protective equipment
<b>STEL</b>	short-term exposure limit
<b>TWA</b>	time-weighted average
<b>USAFSAM</b>	U.S. Air Force School of Aerospace Medicine

## GLOSSARY

**Beryllium work area:** Any work area containing a process or operation that can release beryllium where employees are, or can be reasonably expected to be, exposed to airborne beryllium at any level or where there is the potential for dermal contact with beryllium.

**Carcinogen:** An agent that potentially causes induction of tumors (cancer) following exposure.

**Change room:** An enclosed, self-contained space with washing facilities and separate storage facilities for street and work clothes where employees are able to perform required personal hygiene and don and duff clothing.

**Clean:** To render something or someone free from dirt, marks, pollution, or contamination, especially by washing, wiping, or vacuuming.

**Clubbing of fingers:** Thickening of the tissues at the base of the finger nails such that the normal angle between the nail and the digit is filled in.

**Cross-contamination:** The process by which substances are unintentionally transferred from one object to another, with harmful effect.

**Dermal contact:** Contact with (touching) the skin.

**High efficiency particulate air:** Using a filter generally designed to remove 99.97% of airborne particles measuring 0.3  $\mu\text{m}$  or greater in diameter passing through it.

**Medical surveillance:** The analysis of health information to look for problems that may be occurring in the workplace that require targeted prevention.

**Periodic surveillance:** Assessments or evaluations occurring at intervals of a specific duration.

**Personal hygiene practices:** Conditions or techniques conducive to maintaining health and preventing disease, especially through cleanliness, washing, and wiping.

**Personal monitoring:** Measurements collected in the breathing zones of workers or, in the case of noise, near the ears.

**Regulated area:** An area, including temporary work areas, where an employee's airborne exposure exceeds, or can reasonably be expected to exceed, either the time-weighted average permissible exposure limit or short-term exposure limit.

**Washing facilities:** A location where water and cleaning agents such as soap are available such that employees can clean themselves or launder clothes.